LAT Light Curve Analysis

Robin Corbet
FSSC
corbet@umbc.edu

Photometry

- LAT light curves can be obtained in two basic ways:
  - Likelihood analysis
  - Aperture photometry
- Likelihood analysis has the potential for greater sensitivity. However, aperture photometry is easier and has the benefit of model independence.
- This presentation only deals with aperture photometry.

Tools Used

- Data server
- fkeypar/pget
- gtmktime
- gtselect
- gtbin
- gtexposure
- fdump + external data manipulation scripts

Steps

- It is recommended to use a script to chain together the tools.
  - fkeypar – determine file start and stop times
  - gtmktime – create good time intervals
  - gtselect – filter data based on zenith limit, energy, position, and event class
  - gtbin – make quasi-light curve (counts rather than rate)
  - fdump – export data
  - other tools – convert counts to rates, calculate errors

Get Photon File Start/Stop Times

$ fkeypar "L090923112502E0D2F37E71_PH00.fits[1]" TSTART

(photon start time = 266976000.)

$ fkeypar "L090923112502E0D2F37E71_PH00.fits[1]" TSTOP

(photon stop time = 275369897.)

Filter the Photon File

$ gtselect zmax=105 emin=100 emax=200000 infile=L090923112502E0D2F37E71_PH00.fits outfile=temp2_1DAY_3C454.3.fits ra=343.490616 dec=16.148211 rad=1 tmin=266976000. tmax=275369897. evclsmin=3 evclsmax=10

Parameters specify:
- Energy range (100 to 200,000 MeV)
- Input file is output file from gtmktime
- Source coordinates
- 1 degree radius aperture
- start and stop times previously determined
- evclsmin = 3 for DIFFUSE class

Writes to file: temp3_1DAY_3C454.3

Calculate GTIs

```
$ gtmktime scfile="L090923112502E0D2F37E71_SC00.fits" filter="(DATA_QUAL==1) &&
(angsep(RA_ZENITH,DEC_ZENITH,343.490616,16.148211)+1<105) &&
(angsep(343.490616,16.148211,RA_SCZ,DEC_SCZ)<180)" roicut=n
evfile="temp2_1DAY_3C454.3" outfile="temp3_1DAY_3C454.3"
```

Parameters specify:
- Not in SAA
- photons less than 105 degrees from zenith (+ 1 is because using a 1 degree aperture)
- photon locations less than 180 degrees center of field of view

Writes to file: temp2_1DAY_3C454.3

Extract a Light Curve

$ gtbin algorithm=LC evfile=temp3_1DAY_3C454.3.fits outfile=lc_1DAY_3C454.3.fits scfile=L090923112502E0D2F37E71_SC00.fits tbinalg=LIN tstart=266976000. tstop=275369897. dtime=86400

Parameters specify:
- Make a light curve (LC)
- Input file is output file from gtselect
- Spacecraft file
- Linear time bins
- Start and stop times again
- dtime = 86400: 1 day bins

Writes to file: lc_1DAY_3C454.3.fits

Calculate Exposure of Each Time Bin

$ gtexposure infile="lc_1DAY_3C454.3.fits" scfile="L090923112502E0D2F37E71_SC00.fits" irfs="P6_V3_DIFFUSE" srcmdl="none" specin=-2.1

Parameters specify:
- Spacecraft file
- Instrument response functions (“irfs”). If, for example, SOURCE class rather than DIFFUSE was used in gtselect then use irfs="P6_V3_SOURCE”
- srcmdl – enables a more complex model than the default simple power law to be used in the exposure calculation.
- specin – photon spectral index for power-law spectrum. Note that the negative sign must be used.

An EXPOSURE colume is added to the input file: lc_1DAY_3C454.3.fits

The Output File

- The “final” file will contain Time (in MET), Bin width (s) number of counts in the bin, Error Exposure.
- To convert to rates use e.g. fv or other software to divide counts by exposure. (Also convert from MET to MJD.)
- Error bars in output file are sqrt(counts)
  - For few counts this may be incorrect.
  - To do things correctly is more complicated...

Error Bars (i)

- For errors on a bin containing N photons calculated as sqrt(N).
  - Incorrect for small numbers of photons
  - Gives a zero error if N = 0.
  - Ignores Poisson distribution.
- We often want to know what range of “population” count rates would be consistent with a “sample” of N counts.

Error Bars (ii)

- Several approaches have been proposed.
  - e.g. Gehrels (1986), Kraft et al. (1991), Heinrich (2003)
- One formulation, which gives asymmetric error bars:
  - error = ± 0.5 + sqrt(N + 0.25)
  - e.g. for N = 0, errors are + 1, -0
- Extension of sqrt(N) but based on ends of the error bars.

Error Bars (iii)

- But, using errors based on the observed number of photons is incorrect in many circumstances.
- Number of observed photons exhibits Poisson fluctuations due to shot noise.
- This causes error bars to differ even for bins with the same exposure.
- Can be better to use sqrt(M) where M is the predicted number of photons.


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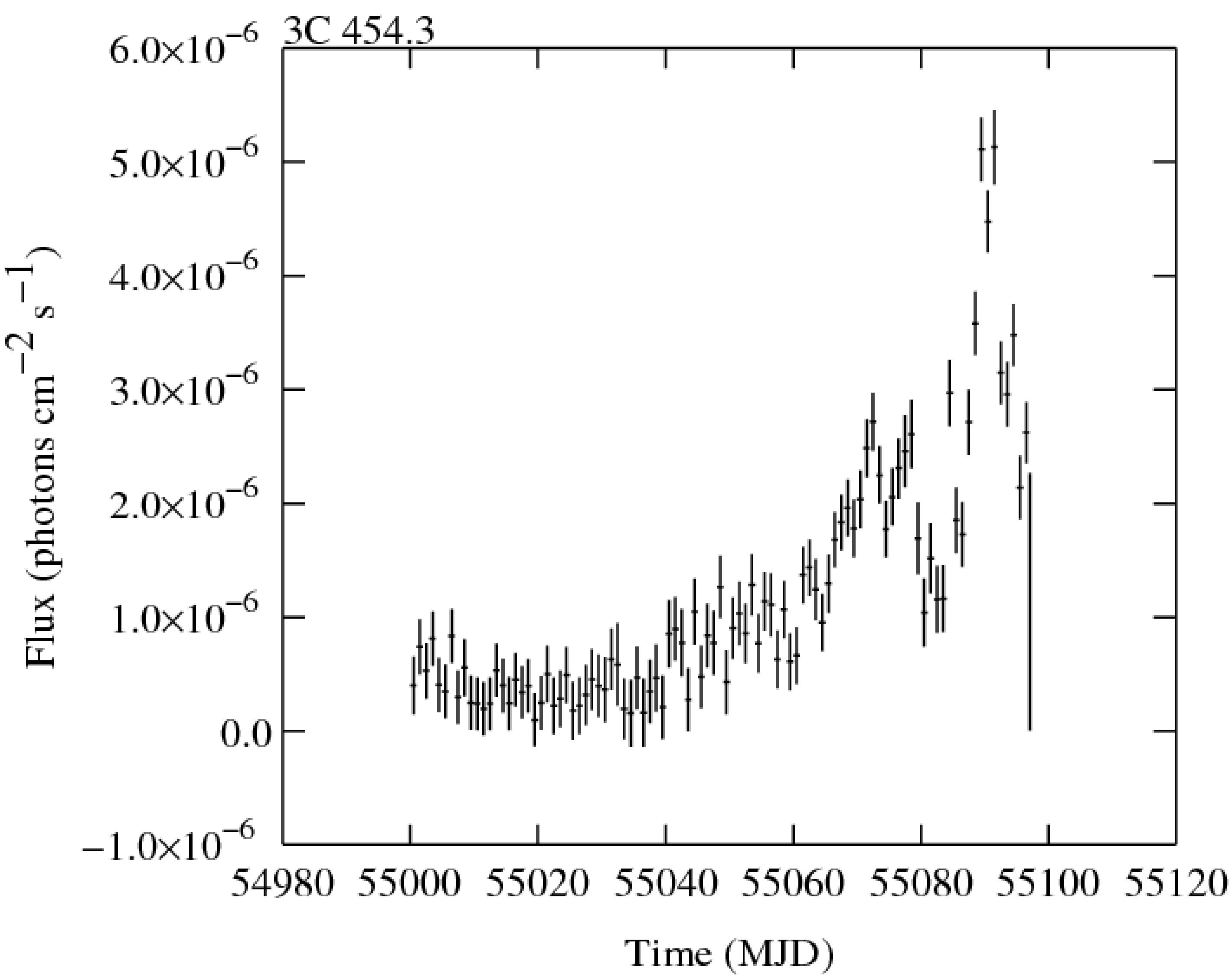
3C 454.3
Flux (photons cm^{-2} s^{-1})
6.0×10^{-6}
5.0×10^{-6}
4.0×10^{-6}
3.0×10^{-6}
2.0×10^{-6}
1.0×10^{-6}
0.0
-1.0×10^{-6}
54980
55000
55020
55040
55060
55080
55100
55120
Time (MJD)

barycentering

- gtbary can also be used to barycenter light curves.
- gtbary must be done as the last step.
  - If you barycenter the photon file the exposure time calculations will be wrong!
- Spacecraft file must cover longer (not same) time range than photon file.
  - Can use gtselect to trim down nominal length of light curve by a small amount.